An audit of extracorporeal membrane oxygenation outcomes in patients with low cardiac output syndrome at Charlotte Maxeke Johannesburg Academic Hospital, South Africa

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Background. Extracorporeal membrane oxygenation (ECMO) is a means of supporting an inefficient cardiorespiratory system, refractory to medical treatment, with a mechanical device. Low cardiac output syndrome (LCOS) is a frequent problem after cardiopulmonary bypass. Globally, centres have investigated outcomes of ECMO and have documented associated preoperative, intraoperative and postoperative predictive factors. Our centre has used ECMO since the mid-1990s, but there has been no study investigating the outcomes.
Objectives. To evaluate 30-day survival and associated predictive factors among patients with LCOS in whom ECMO was used during or after open-heart surgery.
Methods. The study was a retrospective review of clinical records of adult patients in whom ECMO was used during or within 72 hours after open-heart surgery from November 2016 until the end of December 2022. Data were collected using the RedCap (Research Electronic Data Capture) online database manager at the University of the Witwatersrand and entered into a Microsoft Excel spreadsheet. For descriptive analysis, continuous data were analysed using a one-way analysis of variance. The association between patient factors and outcomes was analysed using Fisher's exact test. Statistical analysis was conducted using Stata.
Results. ECMO was used in 4.6% (n=60) of 1 311 patients who underwent heart surgery during the study period, of whom 38 met the study selection criteria; of these, 6 (15.8%) survived to discharge. Of the patients who survived, 5 were black females in the working age group. All the patients who died (n=32/38; 84.2%) did so within 30 days. All the patients experienced morbidity while on ECMO. All the surviving patients survived for >30 days and were discharged from hospital.
Conclusion. Our ECMO survival rate following open heart surgery (~16%) is low compared with other better-established centres. Various factors were associated with the poor outcomes.

Keywords: Charlotte Maxeke Johannesburg Academic Hospital, South Africa, extracorporeal membrane oxygenation, ECMO, post-cardiotomy, outcomes, cardiothoracic surgery

S Afr Med J 2025;115(6):e2341. https://doi.org/10.7196/SAMJ.2025.v115i6.2341

The evolution of cardiac surgery has been marked by considerable challenges. From the late 1800s to the mid-1950s, operations on the heart were performed without a cardiopulmonary bypass (CPB) machine, and mortality was high.[1,2] Open-heart surgery required the development of a CPB machine to improve outcomes.[1,2] CPB is suitable for shorter procedures, but is tolerated less well for extended periods. After open -heart surgery, some patients develop poor heart function and continue to need mechanical support postoperatively.[3] A scaled-down form of mechanical cardiorespiratory support, extracorporeal membrane oxygenation (ECMO), was developed for such situations.

ECMO supports an inefficient cardiorespiratory system that has resulted in a state of low cardiac output. Low cardiac output syndrome (LCOS) occurs when cardiac performance fails to meet the body's metabolic demands. LCOS is a frequent problem after cardiopulmonary bypass and is treated medically, with appropriate intravenous fluids and high doses of various inotropic medications. When medical treatment fails, ECMO is often necessary to assist in myocardial recovery. Utilisation of ECMO is increasing globally,[4-6] including at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH), South Africa (SA).

As ECMO is intended to enable the body and its organs to remain functional while the heart recovers, ECMO is indicated for reversible causes, or used as a bridge to a heart transplant.[5-8] In many cases, the possibility that ECMO will be needed is not anticipated preoperatively. Intensive care unit (ICU) care of a patient receiving ECMO is labour intensive and often associated with complications. Use of ECMO needs to be governed by certain principles to ensure that the patient will benefit from it.[6] Selection of patients is guided by the expected potential for recovery or that the patient will benefit from ECMO as a bridge to a permanent mode of treatment such as a heart transplant. ECMO is not free of risk, as it is associated with complications such as bleeding, organ dysfunction, necessity for reoperation, embolic phenomena and systemic inflammatory response syndrome (SIRS). Bleeding will necessitate transfusion of blood and blood products, while bleeding and an open sternum often necessitate reoperation to evacuate clots and prevent sepsis. Organ dysfunction, in the form of acute kidney injury (AKI) and pulmonary oedema, exacerbates the clinical condition and worsens the prognosis.[8-12]

Hospital statistics show that survival to discharge rates after heart surgery when ECMO was used ranged between 17% and 52%.[13] Importantly, experience with using ECMO, appropriate indications for ECMO, early correction of physiological derangements and prevention of complications contribute to positive outcomes.[14]

Clinical records of cardiac patients at CMJAH show that ECMO has been used since the mid-1990s, but there has been no study investigating the outcomes. To our knowledge, no post-cardiotomy ECMO outcomes in other SA centres have been published.[15,16] The present study therefore aimed to evaluate patients with LCOS requiring ECMO at CMJAH with regard to 30-day survival, length of hospital stay, ICU stay, and preoperative, perioperative and postoperative factors associated with outcome.

Methods

Study site and population

This was a single-centre, retrospective study of patients who required ECMO after open-heart surgery during the period November 2016 - December 2022. The perfusionist consumables list indicated which patients had received ECMO, and records were then analysed to separate out their files. The patient files were examined through the hospital's electronic database, where all patient files are scanned into PDF electronic records.

Study procedures

All adult patients for whom ECMO was used during or within 72 hours after open-heart surgery were included. Paediatric patients undergoing correction of congenital lesions and requiring ECMO were excluded, but we included adult patients with congenital lesions.

Data collection

Study data (demographic and clinical information on patients according to the study objectives) were collected using RedCap 2023 (Research Electronic Data Capture, the online database manager hosted at the University of the Witwatersrand). All collected data were entered into an Excel spreadsheet (Office 16; Microsoft, USA) and formulated, and the data were subsequently transferred to Stata Basic Edition (version 18; StataCorp, USA) for statistical analysis.

Statistical analysis

For normality testing, the Shapiro-Wilk test was used. For descriptive analysis, continuous data were calculated using a one-way analysis of variance and represented as medians and interquartile ranges or means and standard deviations. Categorical variables were represented as frequencies and percentages. Fisher's exact test was used for the association between categorical variables and outcomes. A p-value <0.05 was considered significant.

Ethical approval

Permission to carry out the study was unconditionally granted by the University of the Witwatersrand Human Research Ethics Committee (ref. no. M220618).

Results

Baseline data

Of a total of 1 311 patients who underwent open-heart surgery during the study period, 60 (4.6%) were registered as having had ECMO. Of these, 38 patients (2.9% of the total) met the study selection criteria. There were 20 (52.6%) female and 18 (47.4%) male patients, their ages ranging from 14 to 78 years (the 14-year-old was included in the study based on the hospital criterion that a 14-year-old is managed as an adult patient). Most of the patients (n=30; 79.0%) fell into the working age group (15 - 64 years), followed by the retired/pensioner age group (n=7; 18.4%). Black African patients comprised the largest ethnic group (n=22; 57.9%), other groups (white, Indian and coloured) totalling 16 patients (42.1%). Table 1 summarises the above data. Of the patients, 1 (2.6%) was underweight, 16 (42.1%) had a normal body mass index, and the other 21 (55.3%) ranged from overweight to morbidly obese. With regard to timing of surgery, 15 patients (39.5%) underwent elective surgery, 5 (13.2%) needed to be operated on semi-urgently and 17 (44.7%) urgently, and 1 (2.6%) required salvage surgery.

ECMO outcomes

Table 2 summarises the association between demographic characteristics and outcomes. Of the 38 patients who had ECMO, 34.2% (n=13) were successfully weaned off ECMO and 15.8% (n=5 females and 1 male; p=0.184) survived to hospital discharge following the index hospital admission; 97.4% of the patients (n=37) had ECMO intraoperatively, and in the remaining patient ECMO was used as an emergency 2 days after the index surgery. Just over 84% of the patients (n=32) died during or after ECMO. All the patients who died did so within 30 days. All 6 of the patients who survived were discharged from hospital and survived for >30 days after the index procedure. All the patients developed some form of complication or organ dysfunction (morbidity on ECMO). All ECMO connections were veno-arterial. Four patients (10.5%) had peripheral cannulation. All the survivors were centrally cannulated.

Association between preoperative clinical parameters and 30-day survival

With regard to age, there was no statistical difference between the patients who survived and those who died, but there were preoperative predictors of poor outcome. Although the number of patients was small, patients with lower surgical risk scores (Society of Thoracic Surgery (STS)/EUROScore) tended to have better survival. There was no statistically significant difference with regard to New York Heart Association (NYHA) class (p=1.000). Of the patients who survived, 3 (7.9% of the total) were in NYHA class II, 2 (5.3%) in NYHA class III, and 1 (2.6%) in NYHA IV. All 8 patients who received preoperative intra-aortic balloon pump therapy (21.1% of the total) died (p=0.309). With regard to urgency of the procedure, the elective group had better results (n=3 survivors; 7.9% of the total) than the semi-urgent (n=1; 2.6%) and urgent groups (n=2; 5.3%); however, this was not statistically significant (p=0.871). Twice the number of patients with normal kidney function preoperatively survived compared with patients with abnormal kidney function according to urea (p=0.660) and creatinine levels (p=0.212). Table 3 summarises the association between patient factors and outcomes.

Association between intraoperative parameters and 30-day survival

With regard to indications for ECMO, survival was better in patients with right-sided heart failure. The type of procedure played a

Table 1. Characteristics of the study group (N=38)

Characteristic	n (%)
Age group (years)	
Young (0 - 14)	1 (2.6)
Working age (15 - 64)	30 (79.0)
Retired/pensioner (≥65)	7 (18.4)
Gender	
Male	18 (47.4)
Female	20 (52.6)
Ethnic group	
Black African	22 (57.9)
Other	16 (42.1)

significant role with regard to survival (p=0.010). All the patients who survived had valvular or other cardiovascular procedures, and there were no survivors among patients who had coronary surgery. The duration of the procedure did not have a significant effect on survival (p=0.976), but cardiopulmonary bypass time (p=0.010) and cross-clamp time (p=0.049) were significantly associated with survival. Table 4 summarises the association between intraoperative factors and outcomes.

Discussion

The establishment of cardiopulmonary support devices, such as CPB machines and ECMO systems, and their uses are well documented.[1] The heart tends to function poorly after cardiac surgery, and some patients go into a state of severe LCOS.[2] For those whose hearts are incapable of maintaining acceptable systemic pressures, a mechanical support device is therefore of critical importance until the heart recovers.[3] As reported in the literature, inotropic support plays an important role before a mechanical device is considered, and this was also the case in our patients.[3] ECMO was therefore used only after doing everything possible to avoid mechanical support. The present study analysed the outcomes of patients who received ECMO.

Although statistically insignificant, the survival rate of ECMO patients following cardiac surgery in our unit was low. There was only one survivor in the post-working age group, which is in keeping with other studies showing that older age is not associated with a favourable outcome, especially for older females.[17] In the present study, most survivors were black African females aged <45 years. Patients who survived had less bleeding than those who died, of whom almost all had significant postoperative bleeding and relooks. Another important parameter associated with survival was right-sided heart failure. This group of patients experienced better improvement than those with left-sided or biventricular heart failure. Appropriate patient selection should help improve ECMO outcomes.[4,5] It is unclear how the patients

Table 2. Association between demographic characteristics and outcomes (N=38)

	30-day survival outcome, *n* (%)		
Characteristic	**Alive**	**Died**	***p*-value**
Gender			0.184
Female	5 (13.1)	15 (39.5)	
Male	1 (2.6)	17 (44.7)	
Age (years)			0.897
Young (0 - 14)	0	1 (2.6)	
Working age (15 - 64)	5 (13.1)	25 (65.8)	
Retired/pensioner (≥65)	1 (2.6)	6 (15.8)	
Ethnic group			0.370
Black African	5 (13.1)	17 (44.7)	
Other	1 (2.6)	15 (39.5)	

Table 3. Association between preoperative factors and outcomes (N=38)

	30-day survival outcome, *n* (%)*		
Characteristic	**Alive**	**Died**	***p*-value**
BMI			0.470
Normal	4 (10.5)	12 (31.6)	
Overweight	2 (5.3)	19 (50.0)	
Underweight	0	1 (2.6)	
NYHA			1.000
Class I	0	1 (2.6)	
Class II	3 (7.9)	11 (28.9)	
Class III	2 (5.3)	12 (31.6)	
Class IV	1 (2.6)	8 (21.1)	
Urea			0.660
Normal	4 (10.5)	15 (39.5)	
Abnormally elevated	2 (5.3)	17 (44.7)	
Creatinine (μmol/L), median (IQR)	89.5 (52 - 101)	93 (73.5 - 117)	0.212
Urgency			0.871
Elective	3 (7.9)	12 (31.6)	
Semi-urgent	1 (2.6)	4 (10.5)	
Urgent	2 (5.3)	15 (39.5)	
Salvage	0	1 (2.6)	
Surgical risk scoring, median (IQR)			
STS mortality score	1.02 (0.77 - 1.14)	1.59 (0.94 - 3.04)	0.0001
EUROScore	2.69 (2.42 - 15.32)	3.12 (1.56 - 7.57)	>0.0001

BMI = body mass index; NYHA = New York Heart Association; IQR = interquartile range; STS = Society of Thoracic Surgeons.
*Except where otherwise indicated.

Table 4. Association between intraoperative factors and outcomes (*N*=38)

Characteristic	30-day survival outcome, *n* (%)*		*p*-value
	Alive	Died	
Type of procedure			0.010
Congenital	1 (2.6)	0	
Valvular	2 (5.3)	16 (42.1)	
Coronary	0	12 (31.6)	
Other	3 (7.9)	4 (10.5)	
Procedure			
Duration of procedure (minutes), median (IQR)	410 (370 - 590)	511 (372 - 630)	0.976
CPB time (minutes), median (IQR)	290 (238 - 351)	269.5 (220 - 371.5)	0.010
Cross-clamp time (minutes), median (IQR)	168 (121 - 289)	176 (111.5 - 209)	0.049
Redo sternotomy	1 (2.6)	5 (13.1)	1.000
Preoperative IAPB	0	8 (21.1)	0.309
ECMO cannulation			1.000
Central venous + central artery	5 (13.2)	28 (73.7)	
Opposite femoral artery/vein	1 (2.6)	4 (10.5)	
ECMO connection			1.000
Veno-arterial	6 (15.8)	32 (84.2)	
Type of ECMO			1.000
Central	6 (15.8)	28 (73.7)	
Peripheral	0	4 (10.5)	

IQR = interquartile range; CPB = cardiopulmonary bypass; IAPB = intra-aortic balloon pump; ECMO = extracorporeal membrane oxygenation.
*Except where otherwise indicated.

were selected in our centre. Internationally, selection of patients is usually guided by a special ECMO team.[4,5] Our data show that 4 patients (10.5%) died during surgery after ECMO was started, with bleeding the main problem, causing hypovolaemic shock and subsequent death. The records indicate that only one patient had cardiopulmary resuscitation (CPR) preoperatively and another had CPR postoperatively; ECMO was used to salvage the situation, but neither of these patients survived. ECMO may not be appropriate for patients requiring CPR perioperatively, and an ECMO team would have helped in making the decision whether or not to use it. Complications such as sepsis proved detrimental to weaning off ECMO. For many patients with right-sided heart failure, ECMO was a valuable treatment method to assist recovery.

In our study, preoperative predictors of survival were not statistically significant, but no patient with a poor preoperative physical state who received ECMO survived. A high-risk score (NYHA, STS, EUROScore) preoperatively was also associated with poor outcome when ECMO was used. Preoperative planning for ECMO was considered for the patients undergoing salvage cardiac procedures, but did not affect survival. Intraoperatively, a prolonged surgical time was a factor associated with poor outcome, although this was not statistically significant. Other intraoperative factors such as myocardial protection were poorly documented, so it is unclear whether they contributed to our poor ECMO outcomes.

Bleeding, AKI and sepsis are well-recognised complications of CPB and ECMO,[18] and occurred postoperatively in our patients. Four significant complications, bleeding, AKI, sepsis, and cardiac failure, were noted in most patients who were not weaned off CPB, and almost all patients who had significant bleeding as a complication died. Bleeding was invariably associated with transfusion of significant amounts of blood and other blood products. It is common knowledge that blood transfusion is a risk for SIRS and blood-borne infections. Our study showed that preserved renal function postoperatively was associated with successful weaning off ECMO and subsequent survival to discharge. The duration of ECMO played a role in the development of sepsis, as the sternum remained open for central cannulation, and patients who were subjected to relooks were at an increased risk of sepsis. No patient who developed sepsis while on ECMO was successfully weaned off ECMO. Sepsis was suspected clinically and in some cases confirmed through biochemical markers. In the present study, limb ischaemia while on ECMO was not a good predictor of outcome, as 2 of the patients had lower-limb ischaemia, of whom 1 survived to discharge after a bilateral above-knee amputation. Furthermore, the type of ECMO was mainly central, except for 4 patients who had peripheral cannulation. Mode of cannulation is highly dependent on the clinical indication for ECMO. Generally, veno-venous cannulation is associated with better outcomes than veno-arterial cannulation, which is usually used for patients with a much more severe clinical condition.[19,20] Table 5 summarises the association between postoperative factors and outcome.

The poor outcomes of ECMO in our small patient group were attributable to multiple factors. Most patients had appropriate indications for ECMO, and the few who died on the theatre table probably did not meet the criteria for ECMO. As described in the literature, most centres have a special ECMO team/committee, and lack of such a team in our centre probably led to poor selection of patients for ECMO and therefore increased the number of poor outcomes.

Recommendations

- Formation of a special team to oversee utilisation of ECMO.
- Good recording of clinical data for every patient on ECMO.
- Formulation of selection criteria for ECMO, taking local factors such as funding into consideration.
- A prospective study or studies with good clinical records from other centres in SA would help guide clinicians and funds distributors towards better patient care.

Table 5. Association between postoperative factors and outcomes (*N*=38)

Characteristic	30-day survival outcome, *n* (%)*		*p*-value
	Alive	Died	
1st hour on ECMO			
MAP (mmHg), median (IQR)	60 (52 - 70)	65 (52 - 77.5)	0.395
Pulse rate (bpm), median (IQR)	85.5 (62 - 103)	87 (64 - 100.5)	0.825
Lactate (mmol/L), median (IQR)	4.7 (1.8 - 7.3)	7.6 (5 - 12.6)	0.056
pH, median (IQR)	7.34 (7.28 - 7.35)	7.31 (7.20 - 7.4)	0.000
ECMO			
Duration (days), median (IQR)	3 (1 - 5)	5 (2.5 - 8)	0.011
Relook	6 (15.8)	26 (68.4)	0.562
Complications	4 (10.5)	27 (71.1)	0.302
Organ dysfunction	2 (5.3)	25 (65.8)	0.047
Antibiotic use			
None	0	1 (2.6)	0.203
Prophylactic	5 (13.2)	11 (29.0)	0.203
Empirical	1 (2.6)	11 (29.0)	0.203
Directed	0	9 (23.7)	0.203
Sternum status			
Closed	0	4 (10.5)	1.000
Open	6 (15.8)	28 (73.7)	1.000
Outcome			
Successfully weaned from ECMO	6 (15.8)	7 (18.4)	0.001
ICU stay (days), median (IQR)	7.5 (5 - 10)	7 (4 - 14.5)	0.0001
Hospital stay (days), median (IQR)	22 (20 - 43)	14.5 (8 - 19)	0.001
Discharged from hospital	6 (15.8)	0	0.000

ECMO = extracorporeal membrane oxygenation; MAP = mean arterial pressure; IQR = interquartile range; ICU = intensive care unit.
*Except where otherwise indicated.

Study limitations

Record keeping seems to be a major problem in our hospital, as in many SA public hospitals, and was evident in that, despite ECMO utilisation since the mid-1990s, we could only verify cases from 2016 owing to poor records and lack of a registry of ECMO patients. Much information was missing from files, such as CPB sheets and operative reports. It took a long time to collect data from the hospital's electronic system, because of the multiple pages that are individually stored; collection would have been easier if the information had been grouped in a systematic fashion. There are too few computers available to give a researcher sufficient time to access the necessary information undisturbed, and a shortage of registrars or research support systems such as assistants for data collection adds to the difficulty of involvement in research projects.

Conclusion

This study showed poor survival outcomes of patients on ECMO. However, some patients were successfully weaned off ECMO and survived to discharge. Preoperative, intraoperative and postoperative factors associated with poor ECMO outcomes were identified. CMJAH is one of the few institutions utilising ECMO in SA, and a multifaceted approach regarding selection criteria and ICU management should help improve our ECMO survival rate.

Data availability. The datasets generated and analysed during the present study are available from the corresponding author (NWM) on reasonable request. Any restrictions or additional information regarding data access can be discussed with the corresponding author.

Declaration. The research for this study was done in partial fulfilment of the requirements for NWM's MMed (Cardiothorac Surg) degree at the University of the Witwatersrand.

Acknowledgements. NWM thanks his MMed supervisors, particularly EEN, for their efforts, the research team that contributed to this work, the University of the Witwatersrand, and the Mpumalanga Department of Health for supporting his training. A special thank you to Dr Anteneh Yalew, who was involved in formal data analysis, and Dr Mogamat Junaid, for his involvement with data collection.

Author contributions. NWM: conceptualised the research, collected data, participated in data analysis and write-up. EEN, SMM, ICT and SBN: participated in conceptualisation, supervision, editing and review of the research. No artificial intelligence programs/systems were used in the creation of this article.

Funding. None.

Conflicts of interest. None.

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Received 22 June 2024; accepted 5 March 2025.